Shear-wave birefringence and P- & S-wave delay times in the New Madrid seismic zone

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Scientific objectives of the project.

The University of Wisconsin (UW) deployed an array of 3-component digital instruments in the New Madrid seismic zone to investigate past and present rifting and faulting in the crust and upper mantle. We plan to use P and S time delays from both local and teleseismic events to look for velocity anomalies in a greater depth interval than previous seismic studies in the area, with the time delays from crustal path constrained by the results of the USGS refraction study (Mooney et al., 1983). At individual stations, seismic anisotropy inferred from shear-wave birefringence should reveal tectonic stress vectors that induce microfracture alignment in the upper crust and the preferred crystal-lattice orientation of rock fabrics in the crust and upper mantle.

The project consists of two phases. Phase I, which is a reconnaissance phase, is funded under the above agreement starting 15 February 1991.

Deployment in the New Madrid seismic zone

An array of 12 UW three-component digital seismographs and five PASSCAL Reftek instruments was deployed in the seismic zone from 9 February to 5 April (Figure 1). Station spacing varied from 10 to 30 km due in part to considerable difficulty in finding quiet, unflooded sites in the embayment. The cross-shaped array extended approximately 130 km parallel to the embayment and 150 km perpendicular to the embayment, following USGS refraction lines.

During the deployment, the UW instruments were set to trigger on either local or teleseismic events, and to record at 50 samples/sec, after each trigger, for 60 seconds or 15 minutes, respectively. The Reftek seismographs were set to record continuously at 20 samples/sec. The seismometers used have 1 Hz natural frequency, i.e., Hall-Sears HS10-1 for all UW and two Reftek seismographs, and Geotech S13 for three Reftek seismographs. To evaluate response and performance of these instruments, we co-located the UW instrument with Reftek seismograph at four sites, and co-located a UW or Reftek seismograph with the PANDA (Portable Array of Numerical Data Acquisition) instruments of Memphis State University at three sites, including one site installed with UW, Reftek, and PANDA instruments (Figure 1).

The field observation was approximately 60 days limited by (1) PASSCAL Reftek instruments needing to be returned by early April, and (2) increasing noise level due to farming activities in spring.

Data reduction and analysis

Up to date (three months after the beginning of the project), we have completed transcribing data. Locations of numerous local and regional events have been provided by the PANDA array (Figures 1), and will also be provided by the local permanent networks in the area. Table 1 lists the 35 teleseismic events and number of stations that recorded each event during the deployment, based on comparison between the bi-weekly QDE report and the cluster of UW instrument triggers (minimum three triggers). Most of them have clear P phases (Figure 2a and b), but fewer have good S phases (Figure 2c).

We have gained experience on setting different instrument trigger ratio and gain depending on the noise level and ground condition in the embayment and adjacent highlands. Still at a stage of data reduction, our current analysis includes (1) searching for procedures to separate a teleseismic event from local events or noise, (2) removing chronometer error in Reftek records detected at co-located sites (Figure 2a and b), and (3) comparing data collected by different instruments, and different seismometers at co-locating sites on aspects of frequency content and signal-to-noise ratio (Figure 2).

On necessity of Phase II deployment

Phase I of the New Madrid seismic zone deployment has shown that good P and S phases from both teleseismic and local earthquakes can be recorded by the portable digital instruments at the same site. It was also an opportunity to test the seismographs in a wet, windy, and cold environment. The current data set consists of teleseismic S phases at all sites, and S phases from some local events under the embayment sites for shear-wave birefringence analysis. However, more P and S phases with a better azimuthal coverage must be obtained in order to derive meaningful anomalies through P and S time delays.

In the proposed phase II of the deployment, we plan to use the four winter months when the noise level is at minimum. The key to the winter deployment is the retirement of tape recorders in UW seismographs, the only cold-limiting component in the instrument. They will be replaced by disks, which are now proved to work at -20°C. Modifications to accommodate this is in progress.

Reference cited

Mooney, W.D., M.C. Andrews, A. Ginzburg, D.A. Peters, and R.M. Hamilton, 1983. Crustal structure of the northern Mississippi Embayment and a comparison with other continental rift zones, Tectonophysics, 94: 327-334.

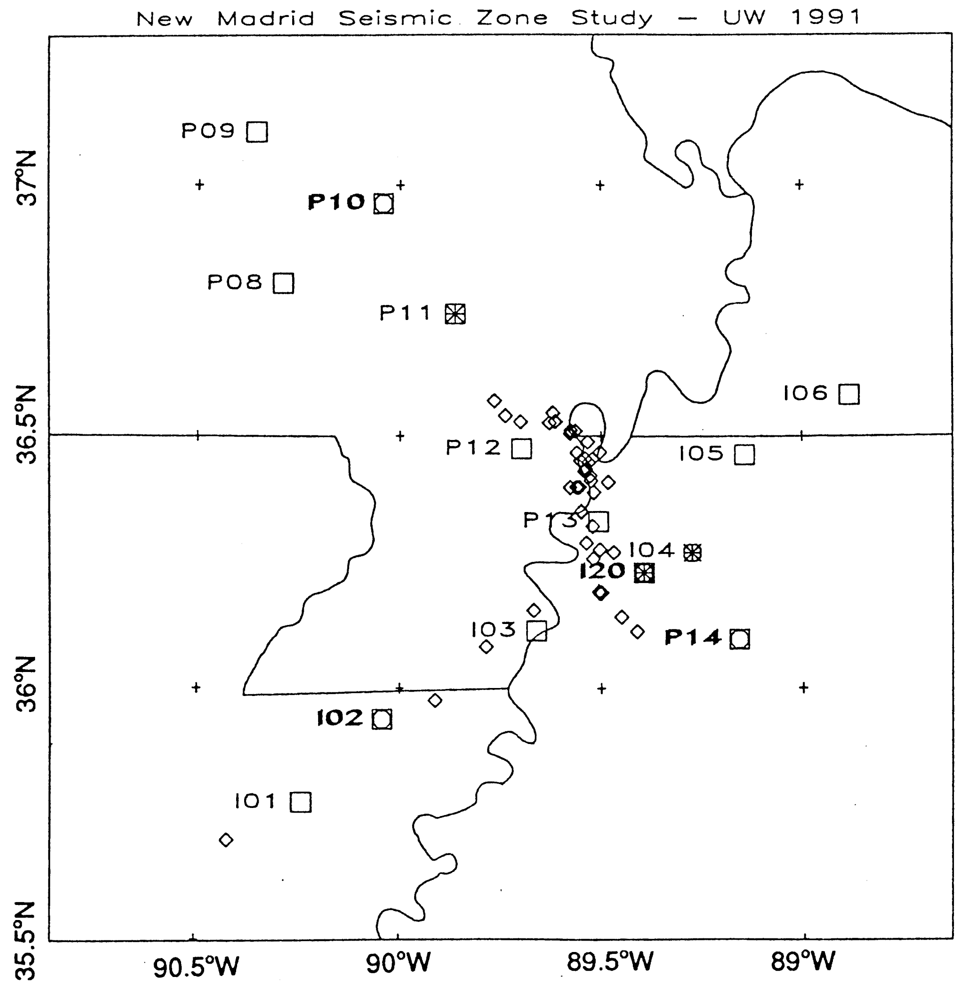

Figure 1. The UW deployment in the New Madrid seismic zone. The cross-shaped array consisted of UW (open squares), and Reftek instrument (hexagons), some of which were co-located with PANDA stations (stars). Locations of seismicity (diamonds) during the deployment (2/9-4/5) shown here were determined from the PANDA array data.

Table 1. Teleseismic Events

No.	Year	Day	Time	Location	Sts.
01	1991	2 12	21 42 29.6	Loyalty Is.	3
02	1991	2 14	16 37 22.5	Gulf of CA	6
03	1991	2 14	23 31 21.3	Easter Is.	7
04	1991	2 16	01 23 40.9	Kuril Is.	10
05	1991	2 18	02 37 28.6	Philippine Is.	8
06	1991	2 18	05 55 50.8	Mexico-Guat.	12
07	1991	2 20	04 48 07.2	Easter Is.	13
08	1991	2 20	21 46 22.4	Papua N. Guinea	7
09	1991	2 20	23 26 27.1	Gulf of CA	8
10	1991	2 21	02 35 32.4	Bering Sea	13
11	1991	2 23	02 42 39.3	Nicaragua	7
12	1991	2 24	11 58 22.8	El Salvador	8
13	1991	2 26	07 25 47.1	Tyrrhenian Sea	9
14	1991	2 27	08 34 35.3	Argentina	9
15	1991	3 01	01 57 03.2	Central Siberia	5
16	1991	3 01	17 30 26.5	Costa Rica	8
17	1991	3 02	03 32 11.9	Guatemala	6
18	1991	3 05	13 49 07.7	C. America	7
19	1991	3 05	22 35 47.3	S. Sumatera	7
20	1991	3 08	09 02 21.6	E. Siberia	9
21	1991	3 08	11 36 30.9	E. Siberia	13
22	1991	3 08	11 55 01.0	E. Siberia	13
23	1991	3 10	12 28 26.7	Colombia	6
24	1991	3 14	15 57 52.2	Aleutian Is.	7
25	1991	3 15	18 50 55.8	Argentina	5
26	1991	3 16	06 02 10.6	Costa Rica	10
27	1991	3 17	06 26 52.2	E. Siberia	4
28	1991	3 19	10 56 17.2	Colombia	4
29	1991	3 19	12 09 24.3	Crete	4
30	1991	3 21	05 53 13.3	Peru	4
31	1991	3 26	12 34 57.7	Dominica	9
32	1991	4 01	05 03 58.1	Mexico	5
33	1991	4 01	07 34 46.4	Mexico	8
34	1991	4 01	09 01 25.2	Mexico	5
35	1991	4 04	03 22 58.4	S. Panama	8

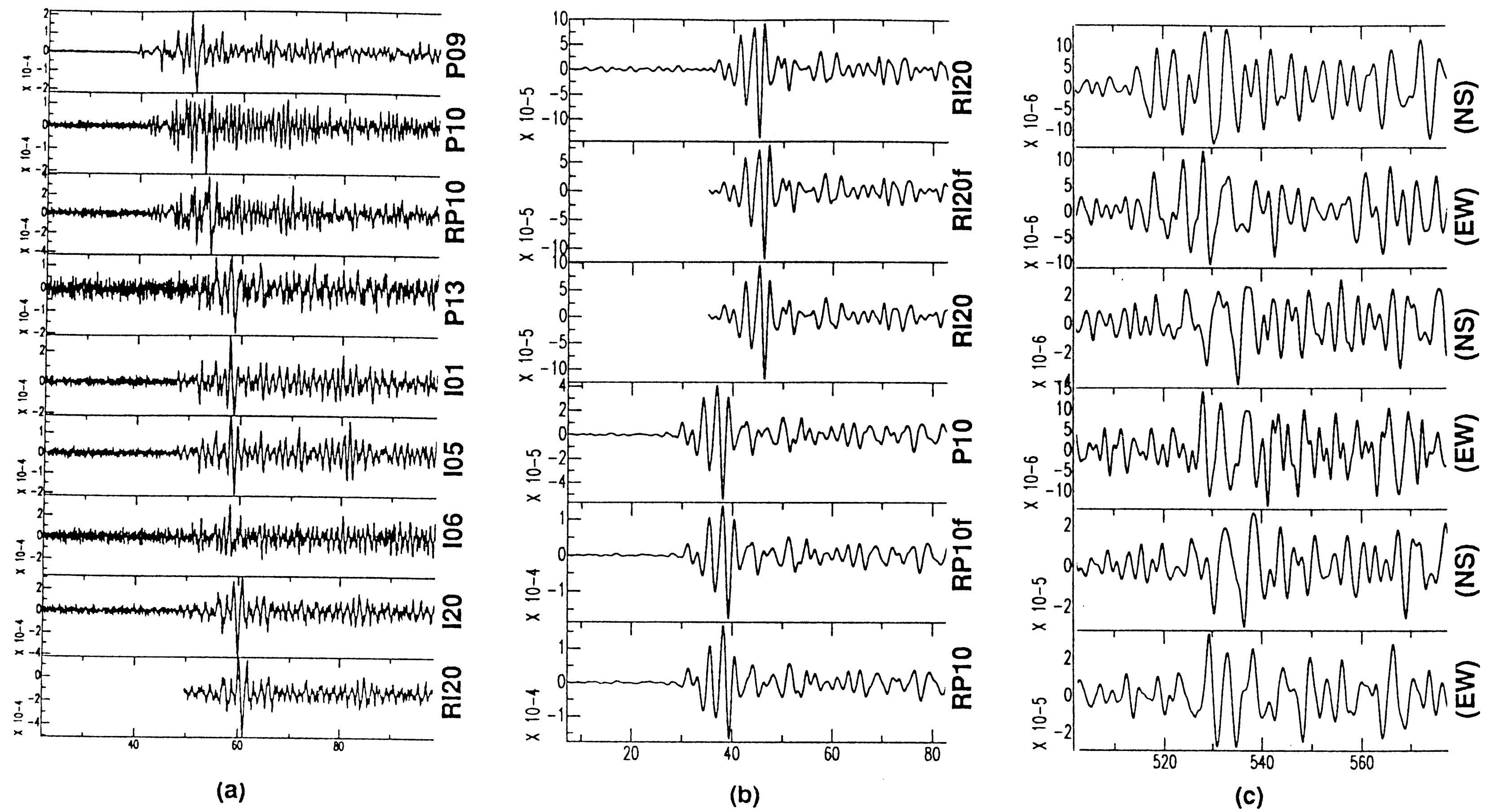

Figure 2. P and S arrivals of a teleseismic event from Bering Sea with $M_B = 6.3$, on Feb. 21. (a) P arrival on the vertical component at nine seismographs. Horizontal scale is in seconds. P10 and RP10, I20 and RI20 are co-located UW and Reftek seismographs. (b) P arrival on vertical component after 2-8 s band-pass filter at co-located UW and Reftek seismographs, where Reftek at RI20 was connected to HS10-1 seismometers, and that at RP10 was connected to S13 seismometers. To make wave forms at the different instruments comparable, a 10 s high-pass filter was applied to the Reftek records at each station (RI20f and RP10f). (c) S arrivals on NS and EW components at Stations P09 and co-located seismograph P10 and RP10. A 2-8 s band-pass filter was applied to each trace, and the high-pass filter was also applied to Reftek records. The ~1 s time difference in the records from co-located UW and Reftek seismographs shown from unfiltered or filtered traces is due to the chronometer error of Reftek.